MUSKINGUM ROUTING OPERATION

Identifier: MUSKROUT

Application: All programs

Description: This Operation is the Muskingum flood routing method as developed by McCarthy (1938).

A description of the Muskingum routing method is in Chapter II.4-MUSKROUT.

In this Operation, the routing time interval is checked to see if it is within the following range for which Muskingum routing works best:

$$K \geq Tr \geq 2Kx \tag{1}$$

    where K is the coefficient that defines a lag or time of travel through the reach
          Tr is routing time interval
          x is a parameter relating inflow and outflow to storage

Both x and K are constant for a given reach in this Operation.

This algorithm will accept routing time intervals not within the range of Equation 1 and still execute the routing Operation. However, during execution, negative outflows can possibly result. If this happens, the routing time interval is divided into 4 equal time sub-intervals. Using linear interpolation, the values of inflow at the intermediate times are calculated. After calculating new c_o, c_1 and c_2 coefficients based on the smaller time interval, Muskingum routing is done on these 4 sub-intervals. The outflow at the end of this procedure is the outflow at the end of the regular routing interval. If this outflow is positive, regular execution continues. If it is still negative, the outflow at the end of the time interval is recalculated by linear extrapolation using the two previous outflows. If this is the first time step for a given run, the outflow is set equal to the initial carryover. If outflow is still negative, it is set equal to zero and normal execution continues.

Routing is normally applied at a reach. However, Muskingum routing can be applied at a point to account for attenuation in the channel system above a headwater gage. In such cases though, variable attenuation routing methods such as lag and K or layered coefficient routing are normally used.

Reference: McCarthy, G.T., 1938: 'The Unit Hydrograph and Flood Routing', presented at conference of North Atlantic Division, U.S. Corps of Engineering, June 1938 (see also 'Engineering Construction - Flood Control', pp. 147-156, the Engineer School, Ft. Belvoir, VA, 1940).

<u>Allowable Time Intervals</u>: 1, 2, 3, 4, 6, 8, 12 and 24 hours

<u>Time Series Used</u>:

General Type	Dimn	Units	Use	Required	Form of Output T.S.	Data Time Interval	Missing Values Allowed
Channel inflow	L3/T	CMS	I	yes	n/a	any	no
Channel outflow	L3/T	CMS	O	yes 1/	additive	2/	yes

1/ Output time series not required if routing is performed at a
   point.

2/ Must be less than or equal to data time interval of inflow time
   series.

<u>Input Summary</u>: The input for this Operation is as follows:

Card	Format	Columns	Contents
1	5A4	1-20	General heading information for this Operation
	2X,2A4	23-30	Internal identifier for the inflow time series
	1X,A4	32-35	Data type code for the inflow time series
	3X,I2	39-40	Data time interval for the inflow time series
	2X,2A4	43-50	Internal identifier for the outflow time series (blank if routing at a point)
	1X,A4	52-55	Data type code for the outflow time series (blank if routing at a point)

Card	Format	Columns	Contents
	3X,I2	59-60	Data time interval for the outflow time series (blank if routing at a point)
	F5.0	61-65	K parameter
	F5.0	66-70	x parameter
	1X,I1	72	Carryover control: 0 = carryover set to zero by default 1 = carryover values read from next data card

Card number 2 needed only if carryover values are to be input.

2	F10.0	1-10	Initial inflow carryover
	F10.0	11-20	Initial outflow carryover

Sample Input and Output: Sample input is shown in Figure 1. Sample output from the parameter print routine is shown in Figure 2. There is no output from the execution routine.

Error and Warning Messages: The error and warning messages generated by this Operation and the corrective measures to take when they occur are as follows:

A. Messages that can occur during setup.

1. **ERROR** OUTFLOW TIME INTERVAL = nnn, IS LESS THAN INFLOW TIME INTERVAL = nnn. THIS IS NOT ALLOWED FOR THIS OPERATION.

Action: Use an outflow time interval that is greater than or equal to the inflow time interval.

2. **WARNING** ROUTING TIME INTERVAL = nn IS NOT WITHIN THE RANGE OF 2.*K*X TO K.

Action: Check Tr, K and x and make sure they are correct.

3. **WARNING** X IS GREATER THAN OR EQUAL TO 0.5. PROBLEMS COULD ARISE IN THE MUSKINGUM ROUTING OPERATION.

Action: Check x to insure it has the proper value.

B. Messages that can occur during execution.

1. **WARNING** IN MUSKINGUM ROUTING FOR general_heading_info CALCULATED OUTFLOWS WERE SET TO ZERO nnn TIMES.

Action: Check the values of parameters x and K and time interval Tr.

Carryover Transfer Rules: The state variables remain the same in the carryover transfer routine.

Punched card limitations: The punched card format is as follows. No checks were made to determine if quantities exceed the maximum allowable value.

Parameters or Variable	Punch Format	Maximum Value	Precision After Decimal Point
K	F5.0	9999.	none
x	F5.4	.9999	ten-thousandths
QIN, QOUT 1/	F10.4	99999.9999	ten-thousandths

1/ Initial inflow and outflow carryover values.

Figure 1. Sample Card Input For Operation MUSKROUT

```
          10        20        30        40        50        60        70        80
     ----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
     KINZUA DAM          KINNE    QINE   6  KINNERTD SQIN    6  11. 0.13
```

Figure 2. Sample Output From Operation MUSKROUT Print Parameter and Print Carryover Routines

```
          MUSKINGUM ROUTING OPERATION FOR REACH KINZUA DAM

                  COMPUTATIONAL TIME INTERVAL IS  6 HOURS

             TIME SERIES USED BY THIS OPERATION

              CONTENTS             I.D.        TYPE      TIME INTERVAL

              INFLOW               KINNE       QINE        6 HOURS

              OUTFLOW              KINNERTD    SQIN        6 HOURS

          PARAMETER VALUES

              ROUTING COEFFICIENTS K = 11.00 HOURS   ROUTING PARAMETER X =   .13

          MUSKINGUM COEFFICIENTS   C0 =      .125    C1 =      .352     C2 =      .523

          CARRYOVER VALUES FOR KINZUA DAM

          INITIAL CARRYOVER VALUES WERE SET TO ZERO
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